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(54) Opto-electronic scale-reading apparatus

Opto-elektronischer Skalenleseapparat

Dispositif opto-électronique de lecture d'une échelle graduée

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Description

The present invention relates to an opto-electronic scale reading apparatus used, for example, to determine the magnitude and direction of movement of one member relative to another. Such an apparatus is typically used on coordinate positioning machines such as machine tools or coordinate measuring machines.

It is known from GB Patent No. 1,504,691 to provide a reflective scale which is scanned by a readhead having an index grating and an analyser grating. The readhead illuminates the scale via the index grating, and a periodic light pattern in the form interference fringes is formed at the analyser grating as a result. Upon relative movement of the scale and the readhead the fringes move across the analyser grating creating, at a given point on the analyser, a light intensity modulation. In one embodiment of the said apparatus, the analyser grating may be positioned so that its lines extend fractionally obliquely to the interference fringes; this results in the generation of moiré fringes. Four photo-detectors behind the analyser grating are offset with respect to a single moiré fringe so that four phase-shifted cyclically varying electrical signals are produced, from which the magnitude and direction of said relative movement may be determined.

GB 1,231,029, proposes, in substitution of the analyser grating, a detector array comprising a plurality of photosensitive elements which combine the functions of the analyser grating and the photo-detectors. In order to provide phase-shifted detection signals, two or more of such detector arrays are required.

Both the above constructions suffer from a disadvantage. If, due to contamination of the scale or the readhead with dirt, the intensity of light incident upon one of the detectors or detector arrays differs significantly from that incident upon the other detectors or detector arrays, the phase-shifted signals produced will be significantly modified. This phenomenon is known as selective contamination, and affects the accuracy of the measurement.

Further documents disclosing structure detector arrays are GB 1,311,275, DE 40 06 789, EP 250 711, EP 143 525 and GB 2,094,974.

The present invention provides opto-electronic scale reading apparatus comprising a scale defined by a series of spaced apart lines, and a readhead, moveable relative to the scale in the direction of spacing of the lines, for generating an output signal from which the magnitude and direction of relative movement of the scale and the readhead may be determined, the readhead comprising:

means for illuminating the scale and generating, in an image plane, a periodic light pattern which varies cyclically in intensity in the direction of spacing of the scale lines, said light pattern having a pitch equal to or smaller than the pitch of said scale lines; a corresponding cyclic variation in light intensity at a given point on said plane resulting from relative movement of said scale and said readhead;

an analyser, positioned in said plane, comprising an array of elongate elements having a photo-sensitive surface exposed to said periodic light pattern, said elements being spaced apart in the direction of spacing of the scale lines and in a direction transverse to their length, said elements being grouped in a plurality of sets with elements of a given set being connected in common, all said elements being interleaved with elements of a different set in a repeating pattern and wherein, the centres of area of the exposed photosensitive surfaces of all elements in a given set are spaced apart by a distance equal to non-zero integer multiple of the pitch of the light pattern;

characterised in that:
the centres of area of the exposed photosensitive surfaces of adjacent elements are spaced apart by a distance equal to the sum of non-zero integer multiple of the pitch of the light pattern and a non-zero fraction of said pitch corresponding to a predetermined phase angle between said adjacent elements with respect to the periodic light pattern.

Because the elements of all of the sets are interleaved each set has elements distributed evenly across the array. The output signal generated by each set of elements is thus derived from light incident upon all areas of the array. Contamination of the apparatus affecting a particular area of the analyser array will therefore affect the output signals of all the sets of elements equally to within the limit of the size of an individual element. The present invention thus provides vastly improved immunity to selective contamination.

Embodiments of the invention will now be described, by way of example, and with reference to the accompanying drawings in which:

Fig 1 is a representation of an opto-electronic scale reading apparatus according to the present invention;

Figs 2a-c illustrate a first embodiment of the present invention;

Fig 3 is a section through a second embodiment of the present invention;

Fig 4 is a plan view of a part of the apparatus of Fig 3;

Fig 5 is a third embodiment of the present invention;

Fig 6 is a fourth embodiment of the present invention; and

Fig 7 is a signal diagram.

Referring now to Fig 1, a light source 10, index grating 12, and scale 14 cooperate to generate a periodic light pattern at an image plane occupied by an analyser 16. The light source 10, index grating 12 and analyser 16 are embodied in a single unit known as a readhead, which is movable relative to the scale 14 in a direction x, which is the direction of spacing of the lines 12A,14A defining the index grating 12 and scale 14 respectively. The magnitude and direction of relative movement between the readhead and the scale 14 is determined by detecting movement of the periodic light pattern across the surface of the analyser 16. The exact configuration of the readhead, or the optical mechanism by which the periodic light pattern is generated at the analyser 16 is not important in this example. Thus, the mechanism disclosed in EP 207121 may be used to generate the periodic light pattern; alternatively, the mechanism shown in GB 1,504,691 may be used. In each case however, the pitch of the light pattern generated is equal to, or less than (e.g. ½ the pitch) the pitch of the scale lines. Typically, the pitch of the scale lines will be between 20 and 40 microns.

The light intensity distribution in the image plane is illustrated in a graph in Fig 2a, and has a substantially sinusoidal shape characterised by peaks 18, corresponding to positions upon the analyser at which a high intensity of light is incident, and troughs 20, corresponding to positions on the analyser at which a low intensity of light is incident. The period, or pitch of the periodic light pattern is denoted in Fig 2 as the distance P.

Fig 2b illustrates the analyser 16 (to the same scale as the graph). The analyser 16 comprises a semi-conductor substrate 22 having, on its surface, an array of elongate photo-sensitive elements 24 spaced-apart in the x direction. Each of the elements 24 is electrically insulated from an adjacent element, by an insulating guard diode 26. The elements 24 are divided into three sets A,B,C and are positioned across the array in an interleaved repeating pattern A,B,C, A,B,C.....; the elements of each set are electrically connected. The spacing between elements 24 of the set A from elements 24 of the set B, and the spacing between elements 24 of the set B from elements 24 of the set C is equal to 1¼ pitches P of the periodic light pattern; the spacing between elements 24 of the set A from elements 24 of the set C is equal to 1½ pitches P of the periodic light pattern. Elements 24 of a given set are therefore spaced from adjacent elements 24 of that set by 4 pitches P of the periodic light pattern (i.e. 1¼+1¼+1½).

As the readhead moves relative to the scale 14 in the direction x the periodic light pattern moves across the surface of the analyser 16. Because all elements 24 of a given set are spaced from each other by an integer multiple of the pitch P of the periodic light pattern, the same intensity of light will be incident upon all the elements 24 of the given set at any given moment in time. Further, the spacing of 1¼ pitches P between elements 24 of the sets A and B, and elements 24 of the sets B and C corresponds to a phase shift of 360° + 90°. Therefore, as the light pattern moves across the surface of the analyser 16 the electrical outputs of the sets A and B, and B and C will vary cyclically, and have phase shift of 90°, as illustrated in Fig 2c. The three outputs of the sets A,B,C may be combined to generate quadrature signals which may then be used to interpolate the magnitude and direction of relative movement of the readhead and the scale. A method of combining the three outputs 24A, B,C to generate such quadrature signals is disclosed in our earlier published patent application WO87/07944.

In an alternative spacing of elements 24 each element 24 is spaced from an adjacent element 24 by 1/3 pitches P. The outputs of the sets A,B,C will, in this embodiment be phase-shifted by 120°.

An analyser array of the above-mentioned type is advantageous over the prior art devices for a number of reasons. The principal advantage however is the insensitivity of the apparatus to selective contamination of individual photo-detectors. In a prior art 3-phase apparatus comprising three individual photo-detectors whose outputs modulate at the same frequency and by the same amplitude but are phase-shifted to enable the generation of a quadrature signal, contamination of a particular area of the scale or of an individual photo-detector would thus disrupt the balance between the three outputs and cause the generation of an imperfect quadrature signal (which would in turn result in inaccuracies in the distance values deduced therefrom). In the present invention, the photosensitive elements 24 are distributed evenly over the entire photo-sensitive area of the analyser 16.
Contamination of any given area of the analyser will thus affect each set of elements A,B,C to approximately the same extent, as will any contamination of a given area of the scale.

As mentioned above, any suitable optical mechanism and configuration of readhead may be used to generate the periodic light pattern. However, the use of an analyser array with a readhead of the type described in GB 1,504,691 has an associated difficulty in that it is difficult to place the index grating and analyser array in mutually coplanar positions. Referring to Figs 3 and 4, a construction of readhead is illustrated which overcomes this difficulty. A scale 110 is read by a readhead 112 provided by an array 114 of photo-emitting elements, and an analyser array 116 (which will not be described further). The photo-emitting array 114 effectively combines the functions of a light source and an index grating. The photo-emitting array 114 and analyser 116 are provided on the same semiconductor substrate, which is typically of gallium arsenide or some other suitable III/V semiconductor material.

The photo-emitting array 114 comprises an area 118 which is a light emitting diode (LED) 120. One of the electrodes for the LED is provided by the common

ground electrode 122 at the rear of the substrate. The other electrode for the LED 120 is a metallisation layer 124 on the front of the substrate. The metallisation layer 124 has the form of a grid pattern which defines elongate apertures 126. In an LED, most of the light emitted originates from areas of the semiconductor material which lie adjacent the electrode. Thus, the regions of the LED 120 which lie in register with the apertures 126 will emit light in a manner very similar to the passage of light through an index grating. This embodiment of the invention provides automatic coplanarity of the photo-emitting array 114 and analyser array 116, while reducing the expense of the apparatus by obviating the need for one or more optical gratings and detectors. This embodiment of the present invention may be particularly useful in an analogue, or scanning probe used, e.g. on a coordinate measuring machine, such as a probe described in WO90/04149.

As mentioned above, the outputs of the sets A,B,C are combined in a number of possible ways to generate quadrature signals. It may be necessary to adjust the amplitude of the individual outputs A,B,C. In the prior art apparatus this is achieved by electrically amplifying or reducing the amplitude of the outputs from individual photodetectors. This is undesirable since additional electronics are required. To overcome this problem, a third embodiment of the present invention enables the optical equalisation of the output amplitudes of the signals from individual sets of photo-sensitive elements.

Referring now to Fig 5, an analyser 160 has a silicon substrate 162 having, on its surface, a plurality of spaced apart photo-sensitive elements 164 each separated from an adjacent element 164 by an insulating guard diode (not shown). In this embodiment, the elements 64 are divided into 4 sets A,B,C,D and the elements 64 are interleaved in a repeating pattern A,B,C, D, A,B,C,D.....; elements of a given set are connected in common. The array 160 may, for the purposes of illustration, be divided into two portions 170,172. Portion 170 of the array includes light sensitive elements 164 wherein the elements 164 of the sets A and B are longitudinally extended in a direction perpendicular to the direction of spacing of the elements with the elements of set A being extended in the opposite direction to the elements of the set B. The elements 164 of sets A and B in portion 170 of the array are thus approximately 10-15% longer than the elements 164 of the sets C and D. Shutters 174,176 are each movable between a first position, and a second position at which part of the array is obscured; specifically, the part of the array on which the extended parts of the elements 164 of the sets A and B lie. By adjusting the position of shutters 174,176 to selectively shutter light from the surface of elements of the sets A and B it is possible to adjust the magnitude of the signal output therefrom. The number of the elements 64 of the sets A and B which are extended longitudinally and the magnitude of the extension depends upon the required range of adjustment of signal strength. Thus, where only a small range of signal strength adjustment is required only some of the elements in the sets A,B need be extended. Portion 172 includes, as with portion 170, four sets of elements A, B,C,D interleaved in a repeating pattern, and with elements of a given set being connected in common (both with each other and with the elements of the corresponding set in portion 170 of the array). In portion 172 of the array 160 elements of the sets C,D are extended longitudinally and shutters 178,180 respectively are provided to enable adjustment of the signal strength output from the sets of elements C,D.

Using the method of selective shuttering described above, it is thus possible to regulate the amplitude of signal output from one or more sets of sensitive elements 64.

As mentioned above, it is desirable to simplify the electronic circuitry used to process the output signals from the various sets of elements. Thus, in addition to providing "optical" adjustment of the amplitude of the outputs from the various sets of signals, the present invention also provides optical adjustment of the relative phase.

Referring now to Fig 6, an analyser array 200 comprises a series of elongate photo-sensitive elements 202 extending substantially in the Y direction, and spaced apart in the X direction. The elements 202 are divided into three sets A,B,C and are interleaved on the array in a repeating pattern; the outputs of elements of a given set are connected in common. As can be seen in Fig 6, the elements 202 of the sets A and C extend substantially parallel both to each other and to the Y direction. However, the elements of the set B extend at a small angle θ to the Y direction. A phase-shutter 204 is provided over the upper ends of the elements 202 and masks part of the elements 202 from the periodic light pattern. The spacing of the elements 202 and the angle at which the elements of set B are slanted relative to the elements of sets A and C is such that when the displacement of the shutter 204 is at the reference displacement R, the centre of area of the exposed portion of the elements 202 of the sets A and B are separated by the same distance in the X direction as the centre of area of the exposed portions of the elements 202 of the sets B and C. The spacing of the elements 202 relative to the pitch P of the periodic light pattern is such that, at the reference displacement R of the shutter 204, the centres of areas of the elements 202 of the sets A and B, and the elements 202 of the sets B and C are spaced from each other by a distance equal to 1¼ pitches P of the periodic light pattern, corresponding to a phase-shift of 360° + 90°. The spacing between the elements 202 of the sets C and A is equal to 1½ pitches P, and thus corresponds to a phase-shift of 360° + 180°.

When the periodic light pattern moves across the surface of the analyser 200 the outputs of the three sets of elements A,B,C will vary cyclically. These cyclically varying outputs are illustrated in the rotating vector dia-

gram of Fig 7, in which each of the outputs A,B,C is represented by an arrow whose angular displacement corresponds to the phase of the output, and whose length corresponds to its magnitude (i.e. amplitude). From the diagram it can be seen that the output of the elements 202 of the set A leads the output of the elements 202 of the set B by 90°; similarly the output of the elements 202 of the set B leads the output of the elements 202 of the set C by 90°. (N.B. In general, in order that the outputs of the elements 5 202 may vary cyclically upon relative movement of the scale and readhead, the width over which each element extends in the X direction-should be a maximum of half the pitch of the light pattern.)

The outputs of the sets A,B,C may be combined according to the combination scheme (A-B), (B-C) to generate two signals having a quadrature relationship. This is only true however provided that the magnitude (i.e. amplitude) of the outputs is equal, and that the phase-shift between the outputs is exactly 90°. Should either the magnitude, or the phase of any one set of elements vary relative to the magnitude or phase of any of the other sets of elements then the resultant signals (A-B), (B-C) will not have a quadrature relationship; errors in the measurement of the position of the readhead relative to the scale will result.

Amplitude adjustment is provided, as with the previous embodiment, by longitudinally extending elements 102 of the set C (for example), and providing a shutter 206 to adjust the exposed area of these elements.

The relative phase of the outputs of elements of the set B is adjusted by movement of the shutter 204 in the Y direction. This has no appreciable effect on the relative amplitude of the output signals from the sets A,B, C, since the phase shutter masks substantially equal amounts of each of the elements 102 of all the sets. However, because the elements 202 of the set B extend at a small angle θ relative to the Y direction, the position of the centre of area of these elements in the X direction shifts in accordance with the displacement of the phase shutter 204. Thus if the phase shutter 204 is retracted from the reference position R, the centre of area of elements 202 of the set B will shift toward elements 202 of the set A and the phase angle between the output of elements of set B and the outputs of elements of set A will decrease. Conversely if the phase shutter 204 is projected from the reference position R then the centre of area of elements of set B will move toward elements of the set C and the phase angle between the output of these two sets of elements will decrease. Typically, the angle θ is a small angle of the order of 1°.

In an alternative embodiment providing phase shift, the elements of one set are shaped so that one end is asymmetrically tapered, thus providing a lateral shift of the centre of area of these elements when a phase shutter is displaced appropriately.

Claims

1. Opto-electronic scale reading apparatus comprising a scale defined by a series of spaced apart lines, and a readhead, moveable relative to the scale in the direction of spacing of the lines, for generating an output signal from which the magnitude and direction of relative movement of the scale and the readhead may be determined, the readhead comprising:

   means (10,12) for illuminating the scale and generating, in an image plane, a periodic light pattern which varies cyclically in intensity in the direction of spacing of the scale lines, said light pattern having a pitch equal to or smaller than the pitch of said scale lines; a corresponding cyclic variation in light intensity at a given point on said plane resulting from relative movement of said scale and said readhead;

   an analyser (16), positioned in said plane, comprising an array of elongate elements (24) having a photo-sensitive surface exposed to said periodic light pattern, said elements being spaced apart in the direction of spacing of the scale lines and in a direction transverse to their length, said elements being grouped in a plurality of sets (A,B,C) with elements (24A,24B, 24C) of a given set being connected in common, all said elements being interleaved with elements of a different set in a repeating pattern and wherein, the centres of area of the exposed photosensitive surfaces of all elements in a given set are spaced apart by a distance equal to non-zero integer multiple of the pitch (P) of the light pattern;

   characterised in that:

   the centres of area of the exposed photosensitive surfaces of adjacent elements are spaced apart by a distance equal to the sum of non-zero integer multiple of the pitch of the light pattern and a non-zero fraction of said pitch corresponding to a predetermined phase angle between said adjacent elements with respect to the periodic light pattern.

2. Apparatus according to claim 1 wherein the elements (202B) of a first of said sets extend at a small angle (θ) relative to the elements (202A,202C) of the other sets, the apparatus further comprising a retractable phase shutter (206) for varying the extent of the photosensitive surfaces of said elements exposed to said periodic light pattern, and thereby varying the spacing between the centres of area of the exposed photosensitive surfaces of elements

(202B) of said first set and the centres of area of exposed photosensitive surfaces of elements of said other sets.

3. Apparatus according to claim 1 wherein said distance between adjacent elements is 1 1/3 of the fringe pitch.

4. Apparatus according to claim 1 wherein said distance between adjacent elements is 1¼ of the fringe pitch.

5. Apparatus according to any one of the preceding claims wherein said analyser further comprises a guard diode (26) positioned between each pair of adjacent elements.

6. Apparatus according to claim 1 further comprising an amplitude shutter (74;76;78;80), retractable from a position at which the amplitude shutter obscures part of the array, wherein one and only one of said sets (A;B;C;D) of elements have photosensitive surfaces which lie on said part of the array obscureable by the amplitude shutter.

7. Apparatus according to claim 6 further comprising a plurality of said amplitude shutters, each provided in respect of one and only one of said sets of elements.

Patentansprüche

1. Optoelektronische Skalenlesevorrichtung, umfassend: eine Skala, die durch eine Serie von beabstandeten Linien definiert ist, und einen Lesekopf, der relativ zu der Skala in der Richtung der Beabstandung der Linien bewegbar ist, um ein Ausgangssignal zu erzeugen, aus dem die Größe und Richtung der relativen Bewegung der Skala und des Lesekopfes bestimmt werden kann, wobei der Lesekopf umfaßt:

   ein Mittel (10, 12), um die Skala zu beleuchten und um in einer Abbildungsebene ein periodisches Lichtmuster zu erzeugen, dessen Intensität sich in der Richtung der Beabstandung der Skalenlinien zyklisch ändert, wobei das Lichtmuster eine Teilung aufweist, die gleich oder kleiner als die Teilung der Skalenlinien ist; wobei eine entsprechende zyklische Änderung der Lichtintensität an einem gegebenen Punkt auf der Ebene aus einer relativen Bewegung der Skala und des Lesekopfes resultiert;

   einen in der Ebene positionierten Analysator (16), der eine Anordnung von länglichen Elementen (24) umfaßt, die eine photoempfindliche Fläche aufweisen, die dem periodischen Lichtmuster ausgesetzt ist, wobei die Elemente in der Richtung der Beabstandung der Skalenlinien und in einer Richtung quer zu ihrer Länge beabstandet sind, wobei die Elemente in einer Vielzahl von Sätzen (A, B, C) gruppiert sind, wobei Elemente (24A, 24B, 24C) eines gegebenen Satzes miteinander verbunden sind, wobei alle Elemente mit Elementen eines anderen Satzes in einem sich wiederholenden Muster verschachtelt sind, und wobei die Bereichszentren der freiliegenden photoempfindlichen Flächen aller Elemente in einem gegebenen Satz durch einen Abstand beabstandet sind, der gleich einem von Null verschiedenen ganzzahligen Vielfachen der Teilung (P) des Lichtmusters ist;

dadurch gekennzeichnet, daß:

   die Bereichszentren der freiliegenden photoempfindlichen Flächen von benachbarten Elementen durch einen Abstand beabstandet sind, der gleich der Summe des von Null verschiedenen ganzzahligen Vielfachen der Teilung des Lichtmusters und eines von Null verschiedenen Bruchteiles der Teilung ist, der einem vorbestimmten Phasenwinkel zwischen den benachbarten Elementen in bezug auf das periodische Lichtmuster entspricht.

2. Vorrichtung nach Anspruch 1, wobei sich die Elemente (202B) eines ersten der Sätze unter einem kleinen Winkel (θ) relativ zu den Elementen (202A, 202C) der anderen Sätze erstrecken, wobei die Vorrichtung ferner eine zurückziehbare Phasenblende (206) umfaßt, um das Ausmaß zu ändern, mit dem die photoempfindlichen Flächen der Elemente dem periodischen Lichtmuster ausgesetzt sind, und um dadurch die Beabstandung zwischen den Bereichszentren der freiliegenden photoempfindlichen Flächen der Elemente (202B) des ersten Satzes und den Bereichszentren der freiliegenden photoempfindlichen Flächen der Elemente der anderen Sätze zu ändern.

3. Vorrichtung nach Anspruch 1, wobei der Abstand zwischen benachbarten Elementen 1 1/3 der Streifenteilung beträgt.

4. Vorrichtung nach Anspruch 1, wobei der Abstand zwischen benachbarten Elementen 1¼ der Streifenteilung beträgt.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der Analysator ferner eine Schutzdiode (26) umfaßt, die zwischen jedem Paar von benachbarten Elementen positioniert ist.

6. Vorrichtung nach Anspruch 1, ferner umfassend eine Amplitudenblende (74; 76; 78; 80), die von einer Position zurückziehbar ist, bei welcher die Amplitudenblende einen Teil der Anordnung verdeckt, wobei einer und nur einer der Sätze (A; B; C; D) der Elemente photoempfindliche Flächen aufweist, die an dem Teil der Anordnung liegen, der durch die Amplitudenblende verdeckbar ist.

7. Vorrichtung nach Anspruch 6, ferner umfassend eine Vielzahl der Amplitudenblenden, von denen jede in bezug auf einen und nur einen der Sätze an Elementen vorgesehen ist.

Revendications

1. Un appareil de lecture à échelle opto-électronique comprenant une échelle définie par une série de lignes espacées et une tête de lecture se déplaçant par rapport à l'échelle dans le sens de l'espacement des lignes afin de générer un signal de sortie permettant de déterminer l'amplitude et la direction du mouvement relatif de l'échelle et de la tête de lecture, la tête de lecture comprenant :

 des moyens (10,12) d'éclairage de l'échelle et de production, dans un plan image, d'un motif lumineux périodique variant de façon cyclique en intensité dans la direction de l'espacement des lignes de l'échelle, ledit motif lumineux ayant un pas égal ou inférieur à celui des lignes d'échelle ; une variation cyclique correspondante de l'intensité de lumière à un point donné sur ledit plan résultant du mouvement relatif de ladite échelle et de ladite tête de lecture ;

 un analyseur (16) placé dans le même plan, comprenant un groupe d'éléments allongés (24) ayant une surface photosensible exposée audit motif lumineux périodique, lesdits éléments étant espacés dans la direction d'espacement des lignes de l'échelle et transversalement à leur longueur, lesdits éléments étant groupés en plusieurs jeux (A,B,C), les éléments d'un ensemble donné (24A, 24B, 24C) étant raccordés entre eux, tous lesdits éléments étant intercalés avec des éléments d'un jeu différent suivant un motif répétitif et où les centres des surfaces photosensibles exposées de tous les éléments d'un jeu donné sont espacés d'une distance égale au multiple entier non zéro du pas (P) du motif lumineux ;

 avec comme caractéristiques :

 les centres des surfaces photosensibles exposées des éléments adjacents sont espacés d'une distance égale à la somme du multiple entier non zéro du pas du motif lumineux et d'une fraction dudit pas correspondant à un angle de phase prédéterminé entre lesdits éléments adjacents par rapport au motif lumineux périodique.

2. Un appareil conforme à la revendication 1 dans lequel les éléments (202B) d'un premier desdits jeux forment un petit angle (8) avec les éléments (202A, 202C) des autres jeux, l'appareil comprenant aussi un obturateur de phase rétractif (206) afin de varier l'étendue des surfaces photosensibles desdits éléments exposés audit motif lumineux périodique et ainsi variant l'espacement entre les centres des surfaces photosensibles exposées des éléments (202B) dudit premier jeu et les centres des surfaces photosensibles exposées des éléments desdits autres jeux.

3. Appareil conforme à la revendication 1 dans lequel ladite distance entre éléments adjacents est de 1 1/3 du pas marginal.

4. Appareil conforme à la revendication 1 dans lequel ladite distance entre éléments adjacents est de 1 1/4 du pas marginal.

5. Appareil conforme à l'une quelconque des revendications qui précèdent dans lequel ledit analyseur comprend aussi une diode de protection (26) placée entre chaque paire d'éléments adjacents.

6. Appareil conforme à la revendication 1 comprenant aussi un obturateur d'amplitude (74;76;78;80) rétractif par rapport à une position à laquelle l'obturateur d'amplitude obscurcit une partie du groupe où un seul desdits jeux (A;B;C;D) d'éléments a des surfaces photosensibles se trouvant sur ladite partie du groupe pouvant être obscurcie par l'obturateur d'amplitude.

7. Appareil conforme à la revendication 6 comprenant aussi plusieurs obturateurs d'amplitude, chacun étant prévu pour un seul desdits jeux d'éléments.

Fig.1.

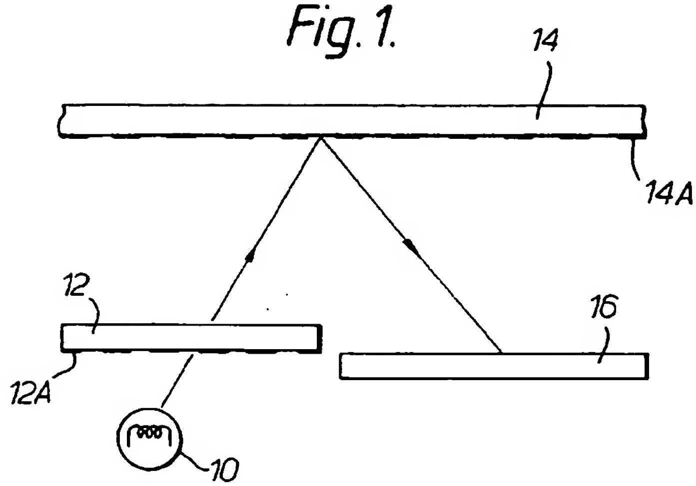
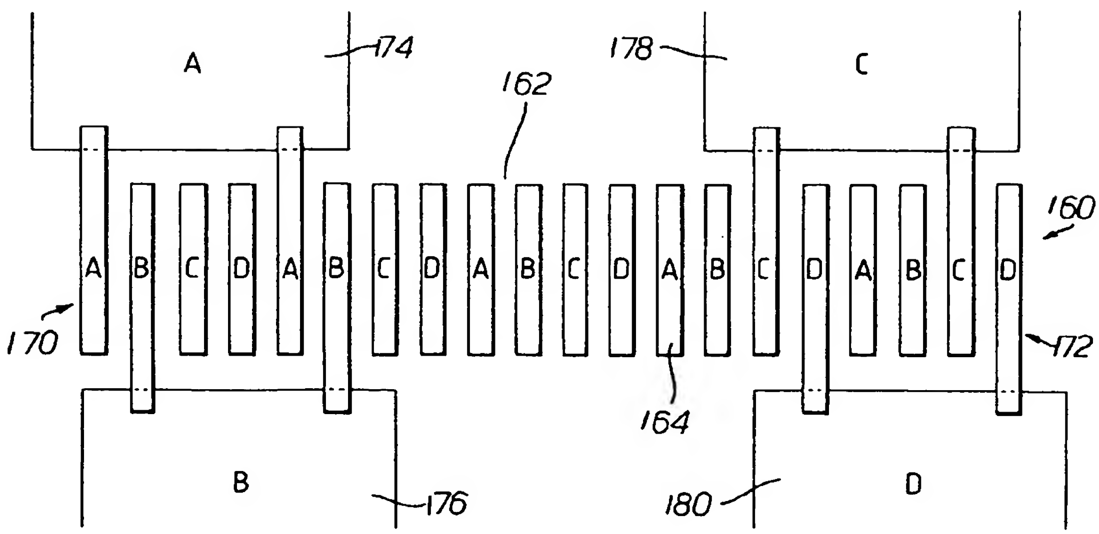

14
14A
12
12A
16
10

Fig.5.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A B C D A B C D A B C D A B C D A B C D
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B
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D

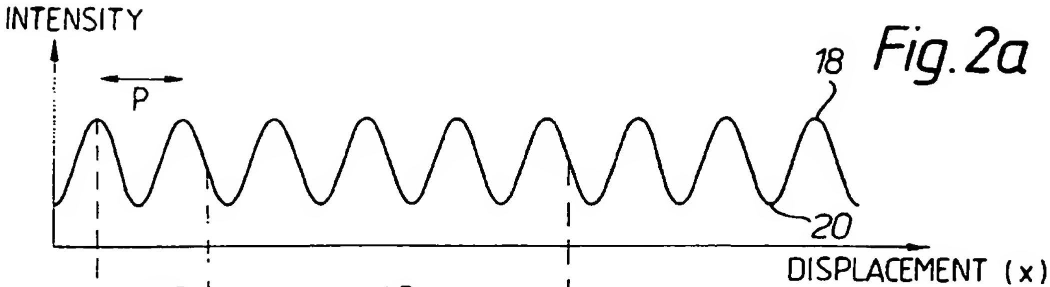


Fig.2a

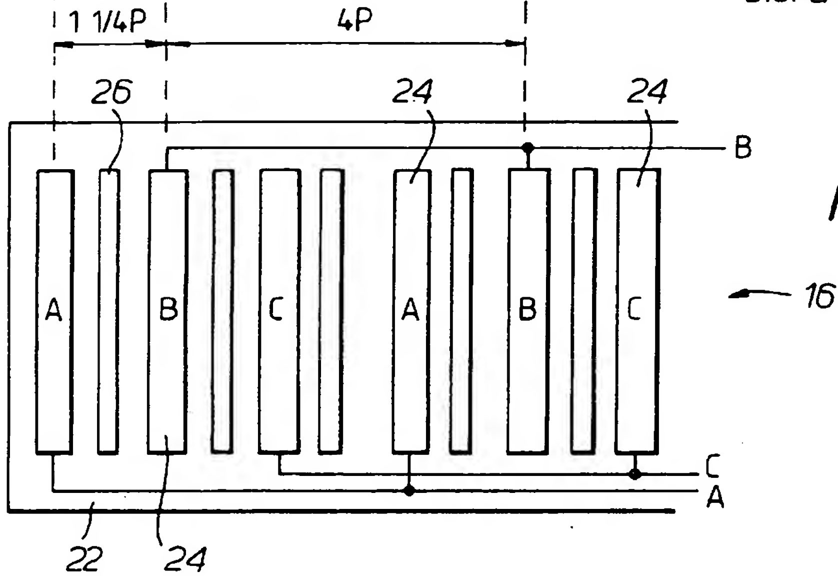


Fig.2b

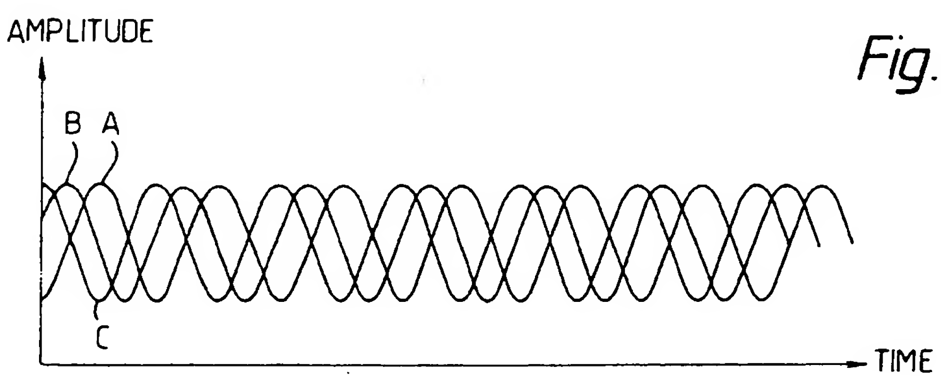


Fig.2c

Fig. 3.

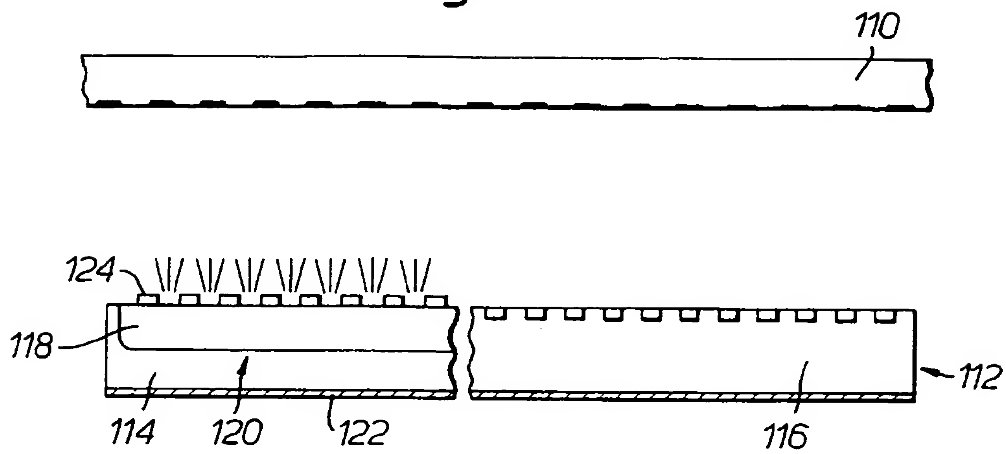


Fig. 4.

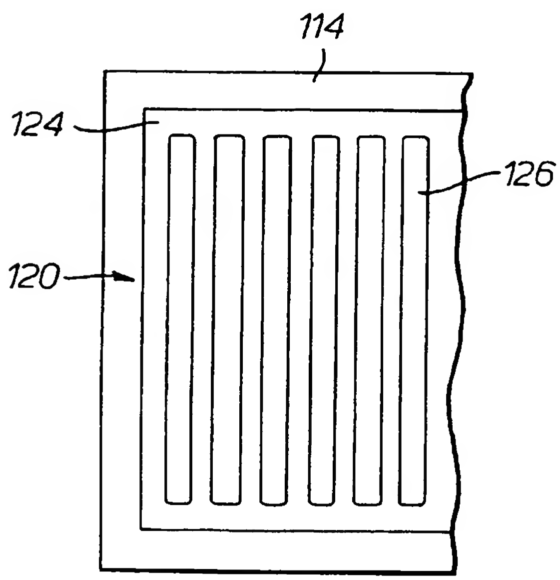
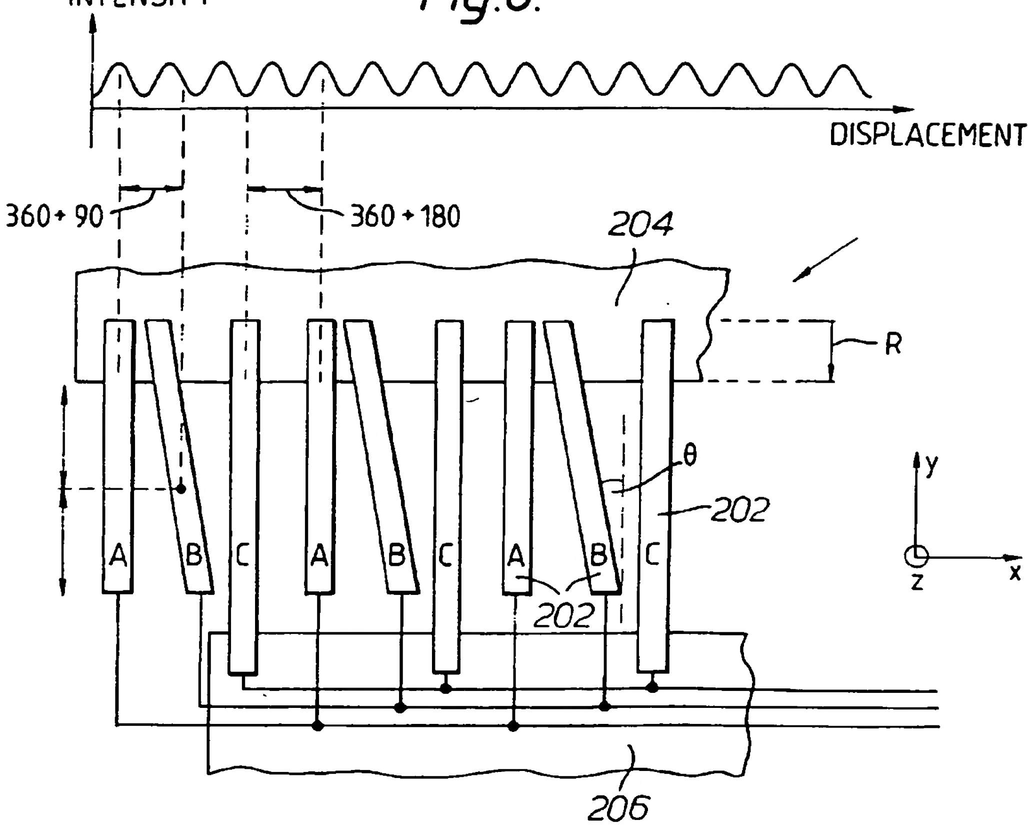


Fig.6.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DISPLACEMENT
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360÷180
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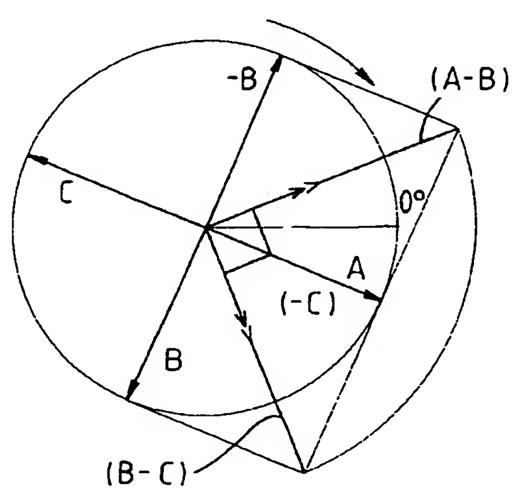
R
θ
202
y
x
z
A
B
C
A
B
C
A
B
C
202
206

Fig.7.


-B
(A-B)
C
0°
A
(-C)
B
(B-C)